# THE INTERTIDAL BENTHIC MACROFAUNA AND SHELLFISH HEAVY METAL CONTENT OF WAIKAWA BAY, MARLBOROUGH SOUNDS, NEW ZEALAND

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ABSTRACT

A quantitative survey of the intertidal macrofauna of Waikawa Bay, Marlborough Sounds, New Zealand (174°01'E, 41°16'S), was carried out during May 1977. Forty-three species of benthic macroinvertebrates were recorded. *Chione stutchburyi* was most prominent, with a maximum density of 2 800/$m^2$ and a maximum biomass of 5 575 g dry weight / $m^2$. Concentrations of lead, zinc, copper and cadmium from four molluscs of different trophic levels *(Chione stutchburyi, Amphibola crenata, Turbo smaragdus* and *Cominella adspersa)* were comparable to levels in other areas in New Zealand and were attributed to natural sources.

## INTRODUCTION

This study, undertaken at the request of the Marlborough Harbour Board, was designed to provide a biological inventory of the intertidal macrofaunal community of Waikawa Bay, Marlborough, prior to possible development of the proposed Waikawa Bay Marina (Marlborough Harbour Board 1977).

Two aspects were investigated; the numerical quantitative distribution of benthic macrofauna, and the concentrations of the heavy metals lead, zinc, copper and cadmium present in shellfish. These data should allow assessment of the effects of nearby urban development on the intertidal macrofaunal community of this area. There have been several physical and cultural studies in this area. The coastal geomorphology of the Marlborough Sounds, including Waikawa Bay, was described by Boyce (1971, 1977). A water quality survey of the Picton Harbour area, including Waikawa and Shakespeare Bays, was presented by the Marlborough Catchment and Regional Water Board (1977). The Environmental Impact Report on the proposed Waikawa Bay Marina (Marlborough Harbour Board 1977) reviews both the physical and socio-economic conditions in this area.

Escourt (1967) surveyed the benthic subtidal fauna of Queen Charlotte Sound including one station (32 m deep) near the mouth of Waikawa Bay and Knox (1973) investigated the subtidal benthic fauna of nearby Shakespeare and Whatamongo Bays. However, there is no known quantitative description of intertidal communities of this area.

## STUDY AREA

Waikawa Bay (174°02'E, 41°16'S) is a U-shaped inlet approximately 2 km long and 1 km wide. At its head, a a bay-head delta, a common feature of the Marlborough Sounds (Boyce 1971), forms a seaward margin to alluvial deposits from the Waikawa Stream. Sediments of the foreshore range in size from very fine silt to 100 mm pebbles derived from weathering of partially metamorphosed greywackes. These were deposited by fluvial processes and sorted by limited wave action and tides. Removal of fine particles from upper foreshore areas has resulted in an exposed berm and fan of coarse material with a slope of 2-5°. The fines have been deposited in flat intertidal zones which are colonised by extensive *Zostera* beds. An intermediate strip of bare silt also borders the streams. In lower tidal areas, sediment reworking has resulted in deposits of coarser sand along with a significant quantity of biogenious material.

## METHODS

### FAUNAL SURVEY

Field work was carried out during spring low tides (18-20 May 1977) to allow sampling of the complete intertidal area. The intertidal zone was divided into eight classes, based upon sediment size, vegetation cover and tidal zones (Table 1). The 29 sampling sites selected encompassed

TABLE 1. CLASSIFICATION ZONES FOR THE INTERTIDAL REGION OF WAIKAWA BAY, MARLBOROUGH SOUNDS, NEW ZEALAND.

| Description | Zone | Station numbers |
|---|---|---|
| Fluvial gravel deposits above MLWN | G | 28, 29 |
| Fine silt overlying gravel | GS | 10, 12 |
| Considerable depth of fine silt | S | 1, 16 |
| Transition between gravel and silt with sparse *Zostera* patches | SZ | 15, 17, 18, 22 |
| Predominantly silt/sand supporting dense *Zostera* beds. Occasional patches of gravel | Z | 2, 5, 6, 7, 19, 24, 25, 26, 27 |
| MLWS level. *Zostera* declining in density and sediment composed of silt/sand and biogenious material | ZW | 3, 8, 11, 13, 20, 21, 23 |
| Below MLWS (0 to -1m). Sparse *Zostera* on fine sand and shell material | W | 4, 14 |
| Greater than 1m below MLWS. Sand with no vegetation | DW | 9 |

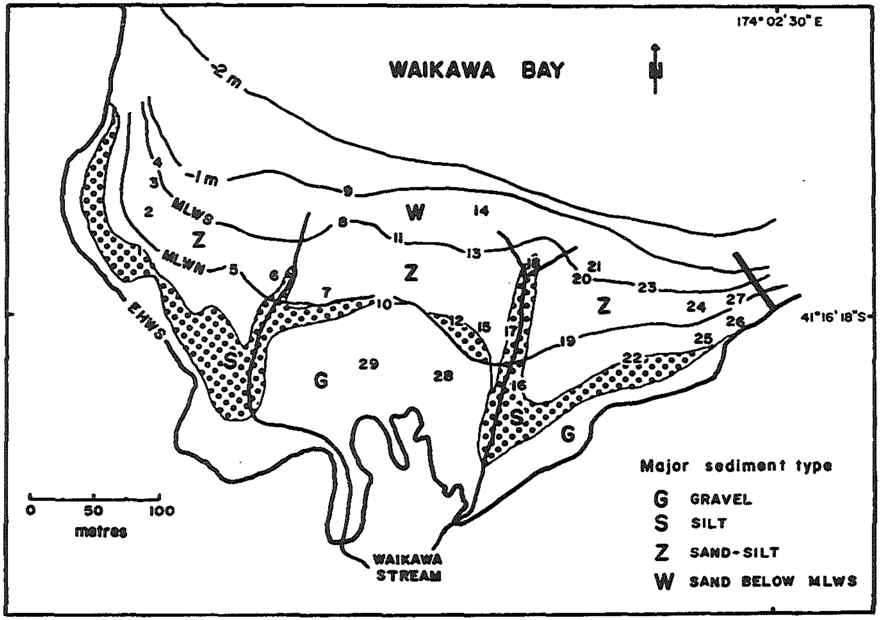


Fig. 1. Map of Waikawa Bay, Marlborough Sounds, New Zealand showing samples sites (1-29), tidal heights and general sediment zones.

TABLE 2. SPECIES DISTRIBUTION AND RELATIVE ABUNDANCE: WAIKAWA BAY, MARLBOROUGH SOUNDS, NEW ZEALAND. MAY 1977. P = PRESENT ($< 200.m^{-2}$), A = ABUNDANT ($> 200.m^{-2}$)

| STATION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | TOTAL STATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample size: $C=7.85x10^{-3}$ $m^2$ $Q=6.25x10^{-2}$ $m^2$ | C | Q | C | Q | C | C | C | C | Q | C | C | C | C | Q | C | Q | C | C | C | C | Q | C | C | Q | Q | C | Q | C | C | |
| Sample zone | S | Z | ZW | W | Z | Z | Z | ZW | DW | GS | ZW | GS | ZW | W | SZ | S | SZ | SZ | Z | ZW | ZW | SZ | ZW | Z | Z | Z | Z | G | G | |
| PLANTS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Hormosira banksii* | | | | | | | | | | | | | | | | | | | | | | | P | | | | | P | P | 3 |
| *Zostera* sp. | | A | P | | A | A | A | P | | | | | P | | A | | | A | A | A | | P | | A | A | A | A | | | 16 |
| ANIMALS - ANTHOZOA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Anthopleura aureoradiata* | | P | | | | | | | | | | | | P | | | | | | | P | | | | | A | A | | | 5 |
| NEMERTEA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Unidentified species | | | | A | | | | | | | | | A | | | | | | | | | | | | | | | | | 2 |
| ANNELIDA - POLYCHAETA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Abarenicola affinis affinis* | | | | | | P | | | | | | | | | | | | | | | | | P | | | | | | | 2 |
| *Aonides trifidus* | | | | | | | | | | A | | | | | | | | | | | | P | | | | | | | | 2 |
| *Axiothella quadrimaculata* | | | P | P | | | | | | | | | P | | | | | | | P | | | A | | | | | | | 5 |
| *Boccardia (Paraboccardia) syrtis* | | | | P | | | | | | P | P | | | | | | A | | A | | | | P | | | | | | | 6 |
| *Capitella capitata* | | | | | | | | | | | | | | | | | | | | | P | | | | | | | | | 1 |
| *Cilliformia tentaculata* | | | | | | | | | | | | | P | | | | | | | | | | | | | | | | | 1 |
| *Glycera americana* | | | | P | | | | P | | | | | | | | | | | | | | | | | P | | | | | 3 |
| *Hemipodus simplex* | | | | | | | | | | | | | P | | | | | | | | | | | | | | | | | 1 |
| *Heteromastus filiformis* | | | | P | | | | | | | | | | | | | | | | | P | | | | | | | | | 2 |
| *Lumbrinereis sphaeracephala* | | | | | | | | | | | | | | | | | | | | | | | | | | | P | | | 1 |
| *Nicon aestauriensis* | | | | | | | | | | | | | | | | | | | | | | | | P | | | | | | 1 |
| *Owenia fusiformis* | | | | | | | | | | | | | P | | | | | | | | P | | | | | | | | | 2 |
| *Orbinia papillosa* | | | | | | | | | | | | | | | | | | | | | P | | | | | | | | | 1 |
| *Pectinaria australis* | | | | | | A | A | | | P | | A | | | | P | A | | | | | P | | | | | | | | 7 |
| *Phylo* sp. | | | | P | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Platynereis australis* | | | | | | | | | | | | | | | | | | | | | P | | | | | | | | | 1 |
| *Polydora polybranchia* | | P | | | | | | | | | | | | | | | | P | | | | | | P | | | | | | 3 |
| *Prionospio pinnata* | | | | | | | | | | P | | | | | | | | | | | | | | | | | | | | 1 |
| MOLLUSCA - AMPHINEURA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Amaurochiton glaucus* | | P | | | | | | | | | | | | | | | | | | | | | | P | P | | | | | 3 |
| GASTROPODA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Notoacmea helmsi* | | | P | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Amphibola crenata* | A | | | | | | | | | | | | | | | P | | | | | | | | | | | | | | 2 |
| *Cominella adspersa* | | | A | | | | | | | | | | | | | | | | | | | | | | | A | | | | 2 |

| STATION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | TOTAL STATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cominella glandiformis* | | P | | | | | | | | | | | P | P | | | | | | | P | | | P | P | | | | | 6 |
| *Diloma subrostrata subrostrata* | | P | | | A | P | P | | | A | | | | P | | P | | P | | P | P | P | | | P | P | P | | | 14 |
| *Micrelenchus dilatutus* | | P | | | | | | | | | | | | | | | | | | | | P | | P | P | | | | | 4 |
| *Turbo smaragdus* | | | | | | | | | | | | | | | | | | | | | P | | P | P | A | A | | | | 5 |
| *Zeacumantus subcarinatus* | P | A | | | A | | P | | | A | | | | P | | | P | | | | P | A | P | P | A | | | | | 12 |
| BIVALVIA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Chione stutchburyi* | P | A | A | A | | | A | A | P | A | A | A | A | P | A | P | P | A | A | A | A | A | A | A | A | | P | | | 24 |
| *Nucula hartvigiana* | | | A | | | | | | P | | | | | | | | | P | | | P | | A | | | | | | | 5 |
| *Paphies australis* | | P | | | | | | | | | | P | | P | | P | | | | | P | P | | | P | | | | | 7 |
| *Perna canaliculus* | | A | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Solemya parkinsoni* | | | | P | | | | | | | | | P | | | | | | P | | | | | | | | | | | 3 |
| *Tellina liliana* | | P | | P | A | | | | P | P | | | | P | P | | P | | P | | | | | | | | | | | 9 |
| ARTHROPODA - CRUSTACEA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Elminius modestus* | | A | | | | | | | | | | | | | | | | | | | | | | | | | | P | P | 3 |
| *Halicarcinus varius* | | P | | | | | | | | | | | | | | | | | | | P | | | | | | | | | 2 |
| *Halicarcinus whitei* | | P | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Hemigrapsus crenulatus* | | P | | | | A | | | | | | | | | | | | | | | P | | | P | P | | | | | 5 |
| *Macrophthalmus hirtipes* | | P | | | | P | | | P | | | | P | | | P | | | | | | | | P | | | | | | 6 |
| ECHINODERMATA - ASTEROIDEA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Patieriella regularis* | | | | | | | | | | | | | | | | | | | | | P | | | | | | | | | 1 |
| Species (total/station) | 3 | 17 | 6 | 9 | 4 | 6 | 5 | 3 | 4 | 8 | 2 | 3 | 9 | 8 | 3 | 6 | 5 | 5 | 5 | 4 | 16 | 8 | 8 | 11 | 11 | 5 | 5 | 2 | 2 | |

the full range of spatial, tidal, sediment and inflow conditions (Fig. 1). At 20 sites, sediment cores of 100 mm diameter (area = $7.85 \times 10^3$ $mm^2$) were taken to a depth of 200 mm and washed through a 0.5 mm aperture sieve. At 9 sites quadrats of 0.0625 $m^2$ area were excavated to a depth of 0.25 m and the sediment washed through a 2 mm aperture sieve. Animals were preserved for later identification. Generalized sediment size trends and community composition were mapped by observations at and around each sample site.

Biomass determinations (g dry weight . $m^{-2}$) were made on samples of the cockle *(Chione stutchburyi)* and the eel grass *(Zostera* sp.), dried to a constant weight at 70°C.

HEAVY METAL ANALYSIS

Four species of mollusc of different trophic levels (deposit feeder - *Amphibola crenata,* filter feeder - *Chione stutchburyi,* herbivore - *Turbo smaragdus,* carnivore - *Cominella adspersa)* were analysed for heavy metal content using standard Atomic Absorption procedures (Millhouse 1975, 1977). Animals were rinsed in clean seawater, frozen within four hours of collection and maintained at approximately -10°C until analysed. Individuals were removed from the shell (operculum intact, as it could not be removed without loss of tissue), dried to a constant weight at 70°C, and digested to a clean solution in a mixture of redistilled nitric acid (95%) and perchloric acid (5%). The digest was slowly evaporated to dryness in electrically heated Kjeldahl flasks and redissolved in 0.5 N redistilled nitric acid. The concentrations of lead, zinc, copper and cadmium were analysed, with reference to standard solutions in the same solvent, using a Varian-Techtron AA5 atomic absorption spectrophotometer. Heavy metal concentrations were calculated as micrograms (Ug) per gram shell-free dry weight for each individual. Fifteen individuals were analysed from each sample except for *Cominella adspersa* where five individuals were analysed.

## RESULTS

FAUNAL SURVEY

Table 2 presents the 43 species recorded in this survey; their distribution and relative abundance (mollusc nomenclature follows Powell 1976).

The eel grass *(Zostera* sp.) formed dense beds in parts of the study area (Table 3). Its maximum biomass was 1200 g dry weight . $m^{-2}$.

TABLE 3. BIOMASS OF *ZOSTERA* (g DRY WEIGHT AT 70°C . $m^{-2}$) IN WAIKAWA BAY, MARLBOROUGH SOUNDS, NEW ZEALAND, 19 MAY, 1977.

| Station | Biomass |
|---|---|
| 2 | 453.4 |
| 5 | 617.9 |
| 18 | 382.2 |
| 24 | 1199.2 |
| 26 | 856.1 |
| 27 | 308.0 |

The cockle *(Chione stutchburyi)* was the most prominent animal, being present at 24 of the 29 sample sites. The maximum *Chione* density was 2800 . $m^{-2}$ at station 18. To compensate for the great size and age variation in individuals, the quantitative distribution of *Chione* is also expressed in terms of biomass (g dry weight of the whole animal . $m^{-2}$) (Table 4). A maximum biomass of

TABLE 4. DENSITY (NUMBERS . $M^{-2}$) AND BIOMASS (G DRY WEIGHT . $M^{-2}$) OF *CHIONE STUTCHBURYI* IN WAIKAWA BAY, MARLBOROUGH SOUNDS, NEW ZEALAND, 19 MAY 1977.

| Station | Density | Biomass | Station | Density | Biomass |
|---|---|---|---|---|---|
| 1 | 127 | 400.0 | 16 | 0 | 0 |
| 2 | 208 | 272.5 | 17 | 127 | 4.9 |
| 3 | 2038 | 4317.0 | 18 | 2082 | 3986.3 |
| 4 | 224 | 392.3 | 19 | 764 | 2297.0 |
| 5 | 0 | 0 | 20 | 637 | 46.2 |
| 6 | 0 | 0 | 21 | 384 | 2609.8 |
| 7 | 255 | 119.8 | 22 | 0 | 0 |
| 8 | 382 | 3128.9 | 23 | 637 | 5575.0 |
| 9 | 64 | 68.6 | 24 | 736 | 1865.9 |
| 10 | 637 | 44.6 | 25 | 224 | 133.1 |
| 11 | 637 | 3043.6 | 26 | 0 | 0 |
| 12 | 892 | 268.8 | 27 | 32 | 406.8 |
| 13 | 892 | 1011.6 | 28 | 0 | 0 |
| 14 | 32 | 149.8 | 29 | 0 | 0 |
| 15 | 1146 | 80.2 | | | |

5575 g dry weight . $m^{-2}$ was recorded at Station 23. The high densities recorded at Stations 10, 15, 17 and 20 were due to individuals less than one year old, and these stations had a relatively low biomass. As *Chione* was the dominant organism in the bay, both in size and numbers, the total macrofaunal biomass would not be much greater than that of *Chione* alone.

TABLE 5. NUMBER OF SPECIES (MEAN AND MAXIMUM) RECORDED FROM EACH ZONE OF WAIKAWA BAY, MARLBOROUGH SOUNDS, NEW ZEALAND, 19 MAY 1977. (ZONE NOTATION AS IN TABLE 1).

| Zone | G | GS | S | SZ | Z | ZW | W | DW |
|---|---|---|---|---|---|---|---|---|
| Species number | | | | | | | | |
| Mean | 2 | 5.5 | 4.5 | 5.2 | 7.6 | 6.9 | 8.5 | 4 |
| Maximum | 2 | 8 | 6 | 8 | 17 | 16 | 9 | 4 |

Table 5 presents the number of species in the community supported by each zone of the study area. The greatest number of species was observed in the areas colonized by *Zostera*, especially those areas with a sand/silt substrate (zones Z, ZW), and the least number of species in the fluvial gravel deposits above MLWN (zone G).

TABLE 6. HEAVY METAL CONTENT ($Ug.g^{-1}$ DRY WEIGHT) OF SHELLFISH COLLECTED FROM WAIKAWA BAY, MARLBOROUGH SOUNDS, NEW ZEALAND. 19 MAY 1977. (SD = STANDARD DEVIATION).

| Species | Station | n | Lead | | | Zinc | | | Copper | | | Cadmium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mean | range | SD | mean | range | SD | mean | range | SD | mean |
| *Amphibola crenata* | 1 | 15 | 8.20 | <10.7 | 3.1 | 54.56 | 29.8-105.2 | 17.4 | 98.28 | 48.9-262.6 | 48.9 | Less |
| (deposit feeder) | 16 | 15 | 11.75 | <18.3 | 5.4 | 64.17 | 12.8-87.5 | 22.2 | 109.47 | 75.3-154.6 | 27.9 | than |
| *Chione stutchburyi* | 2 | 15 | 12.46 | <14.58 | 2.7 | 108.04 | 71.1-232.7 | 47.3 | 44.81 | 22.2-160.0 | 36.3 | 0.015 |
| (filter feeder) | 8 | 15 | 17.05 | <52.78 | 12.6 | 112.16 | 65.7-180.8 | 32.7 | 70.17 | 9.9-371.8 | 101.8 | $Ug.g^{-1}$ |
| | 21 | 15 | 14.32 | <47.28 | 14.9 | 87.62 | 8.0-298.1 | 75.9 | 19.97 | 9.6-28.4 | 11.2 | in all |
| | 26 | 15 | 8.78 | 1.5-17.9 | 7.7 | 76.12 | 51.9-152.5 | 25.4 | 65.55 | 34.2-142.9 | 30.4 | cases |
| *Turbo smaragdus* (herbivore) | 26 | 15 | 19.18 | 13.4-25.3 | 3.7 | 98.30 | 50.6-148.8 | 25.3 | 117.93 | 79.6-166.8 | 28.9 | |
| *Cominella adspersa* (carnivore) | 26 | 5 | 5.09 | 2.2-9.1 | 2.8 | 68.62 | 33.1-101.0 | 24.1 | 71.89 | 36.6-117.2 | 30.2 | |

## HEAVY METAL ANALYSIS

Table 6 lists the mean, range and standard deviation of heavy metal concentrations observed at each station. Cadmium was not detected in this analysis (the sensitivity of which was calculated to be 0.015 $ug.g^{-1}$). Lead concentrations in several individuals were below detection limits, and the minimum detectable level was used when calculating a mean concentration. Therefore, the mean values for lead at all stations except 26 are the maximum possible mean lead content of the sample.

# DISCUSSION

## FAUNAL SURVEY

The species distribution data given in Table 6 indicate that tidal position, and the consequent substrate type are the main factors affecting community structure. The protected stuation of the bay enhances the relatively stable substrate distribution. The very shallow zone of anaerobic sediment observed at most stations showed that the sediments are rarely disturbed to a depth greater than 20 mm.

The exposed coarse gravel deposits of the upper foreshore supported only two species; the alga *Hormosira banksii* and the barnacle *Elminius modestus*. The number of species present increased through the silt deposits about mid tide level (typified by *Amphibola crenata* ), to a maximum at mean low water level. The silt and fine sand of the *Zostera* flats, which have been created between MLWN and MLWS, were colonized by a very typical *Zostera* community as described by Morton and Miller (1973). The major species were the bivalves *Nucula hartvigiana* and *Solemya parkinsonii,* the gastropods *Notoacmea helmsi, Turbo smaragdus* and *Diloma subrostrata subrostrata,* the crabs *Halicarcinus whitei* and *Hemigrapsus crenulatus* and the polychaetes *Glycera americana* and *Platynereis australis*.

Areas of clean sand and *Zostera* about MLWS supported the maximum *Chione* biomass (Table 4).

Estcourt (1967) found similarly that water depth and sediment type were important in determining the distribution of the subtidal fauna of this area.

Community structure across the bay varied relatively little, although the following differences were seen. The sediments at the east end of the tidal flat (Stations 24-27) contained a higher silt fraction. The biomass of *Zostera* was higher (Table 3), and it supported the highest density of the herbivore *Turbo smaragdus*. *Chione stutchburyi,* although more evenly distributed along the low tide level, exhibited its highest biomass toward the east. The firm substrate of the west end of the tidal flat (Stations 2-3) supported the highest number of species (17), including a few green mussels, *Perna canaliculus*, attached to debris among the sediment.

The direct effects of freshwater inflow from the Waikawa Stream on the intertidal community appeared to be minimal. No species typical of very low salinity were observed, and there was little reduction in species number or animal density near the stream inflow. However, because the sediments in Waikawa Bay come primarily from the Waikawa Stream, and sediment patterns in the intertidal area are affected by changes in discharge (Boyce 1977), the stream is important indirectly in structuring the macrofaunal community in the bay.

## HEAVY METAL ANALYSIS

Although they occur in concentrations of less than 0.01 ppm in seawater, some heavy metals are readily accumulated by shellfish (Brooks and Rumsby 1965). Nielsen and Nathan (1975) pointed out that New Zealand is geologically young and relatively rich in natural heavy metals of volcanic origin, and that leaching and transport to the sea by streams and rivers has led to large local variations in heavy metal levels. Individual variation in metal concentration was very large in this study and as a result no spatial or species trends are obvious. Boyden (1974) noted that heavy metal content of a particular mollusc species may vary when expressed on a weight basis, with the size of the individual.

There are few local studies with which these results may be compared. In comparison to "normal" concentrations presented for *Chione stutchburyi* by Nielsen and Nathan(1975) and Millhouse (1975, 1977) (Table 7); those obtained in

TABLE 7. COMPARISON OF MEAN HEAVY METAL CONCENTRATIONS OF *CHIONE STUTCHBURYI* (UG.G$^{-1}$ DRY WEIGHT) RECORDED FROM WAIKAWA BAY WITH OTHERS FROM NEW ZEALAND WATERS. (THE VALUES OF NIELSEN AND NATHAN (1975) HAVE BEEN INCREASED BY A FACTOR OF 8 TO CONVERT μg g$^{-1}$ WET WEIGHT TO UG.G$^{-1}$ DRY WEIGHT).

| | Lead | Zinc | Copper | Cadmium |
|---|---|---|---|---|
| Nielsen and Nathan 1975 | 14 | 80 | - | 1.5 |
| Millhouse 1975, 1977 | 14-94 | 15-416 | 7-211 | 1-10 |
| Present study | 8-17 | 76-112 | 19-70 | .02 |

this study are very low for cadmium, and comparable for lead, zinc and copper. As Waikawa Bay is free from any major pollution source (Marlborough Catchment and Regional Water Board 1977), the observed heavy metal concentrations are probably from natural sources.

## CONCLUSION

The water of Waikawa Bay is usually at a class "A" level (natural state - New Zealand Water and Soil Conservation

Act 1967), with moderately low coliform bacterial counts in sand, water and shellfish even during high summer recreational use (Marlborough Catchment and Regional Water Board 1977). The present study showed that the intertidal benthos of Waikawa Bay supports a macro-invertebrate community of forty-three species. Distribution patterns showed a strong relationship to tidal position and related sediment characteristics, with maximum number of species and animal numbers being found between MLWN and MLWS levels. The observed low to moderate natural heavy metal levels present in shellfish further highlight the high water quality classification given to the bay.

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